(2)

USACERL Technical Report P-90/15
June 1990
DEH Equipment Maintenance Management System

US Army Corps
of Engineers
Construction Engineering
Research Laboratory

AD-A226 175

Modeling the Economic Effects of Using Alternate Fuels in Light Trucks for U.S. Army Installation Directorates of Engineering and Housing

by
Donald K. Hicks
Patrick J. Tanner
Michael J. Fuerst

This research models the economic effects of using alternate fuels in the Army Directorate of Engineering and Housing (DEH) fleet of light trucks. A background investigation identified current government and private industry use of compressed natural gas (CNG) and liquefied petroleum gas (LPG, or propane). After a background investigation, an economic model was proposed, which included: Refueling Station Costs, Vehicle Conversion Costs, Fuel Costs, and Changes in Operation and Maintenance Costs. Safety and environmental effects are discussed, but not quantified.

The model includes vehicle data collected from three Army installations. Economic payback analyses were performed for various fleet scenarios. Sensitivity analyses were performed by varying the costs associated with certain parameters of the model.

Results indicate that within the 20-year period of analysis, the price difference between neither CNG nor LPG and gasoline would realize a sufficient economic payback to justify conversion.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1990	Final

4. TITLE AND SUBTITLE

Modeling the Economic Effects of Using Alternate Fuels in Light Trucks for U.S. Army Installation Directorates of Engineering and Housing

5. FUNDING NUMBERS

PE 4A162731
PR AT41
TA SB
WU CG9

6. AUTHOR(S)

Donald K. Hicks, Patrick J. Tanner, and Michael J. Fuerst

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratory (USACERL)
PO Box 4005
Champaign, IL 61824-4005

8. PERFORMING ORGANIZATION REPORT NUMBER

TR P-90/15

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

USAEHSC
ATTN: CEHSC-FB-I
Bldg 358
Fort Belvoir, VA 22060-5516

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This research models the economic effects of using alternate fuels in the Army Directorate of Engineering and Housing (DEH) fleet of light trucks. A background investigation identified current government and private industry use of compressed natural gas (CNG) and liquefied petroleum gas (LPG, or propane). After a background investigation, an economic model was proposed, which included: Refueling Station Costs, Vehicle Conversion Costs, Fuel Costs, and Changes in Operation and Maintenance Costs. Safety and environmental effects are discussed, but not quantified.

The model includes vehicle data collected from three Army installations. Economic payback analyses were performed for various fleet scenarios. Sensitivity analyses were performed by varying the costs associated with certain parameters of the model.

Results indicate that within the 20-year period of analysis, the price difference between neither CNG nor LPG and gasoline would realize a sufficient economic payback to justify conversion. Keywords

14. SUBJECT TERMS

light trucks
economic impact
compressed natural gas
fuels
propane

15. NUMBER OF PAGES

38

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (USAEHSC) under project 4A162731AT41, "Military Facilities Engineering Technology"; Task SB; Work Unit CG9, "DEH Equipment Maintenance Management System." The USAEHSC Technical Monitor was Mr. Walter Seip, CEHSC-FB-I.

This research was performed by Tanner and Associates Consulting and Analytical Services and the Facilities Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). Mr. Donald Hicks was the USACERL Principal Investigator for the project and Michael Fuerst the Associate Investigator. Dr. Michael J. O'Connor is the Chief of USACERL-FS. The USACERL technical editor was William J. Wolfe, Information Management Office.

LTC E.J. Grabert, Jr. is Commander of USACERL, and Dr. L.R. Shaffer is Director.

CONTENTS

FIGURES

TABLES

TABLES (Cont'd)

MODELING THE ECONOMIC EFFECTS OF USING ALTERNATE FUELS IN LIGHT TRUCKS FOR U.S. ARMY INSTALLATION DIRECTORATES OF ENGINEERING AND HOUSING

1 INTRODUCTION

Background

Each U.S. Army installation Directorate of Engineering and Housing (DEH) operates a fleet of light trucks powered by gasoline engines. The uncertainty of gasoline prices for the past 15 years has caused the U.S. Army Corps of Engineers and the U.S. Army Engineering and Housing Support Center to consider the changes in relative prices which would justify a conversion of the light truck fleets to liquefied petroleum gas (LPG, or propane) or compressed natural gas (CNG). Propane and CNG were chosen for study because existing technology can support conversions to them, and because many Army installations have the capability to store and distribute these and other alternative fuels. Conversion to these may reduce fuel and vehicle maintenance costs and extend vehicle engine life.

Objective

The objective of this report is to model the economic effects of using propane or CNG on Army installations as alternate fuels to gasoline in light truck fleets, and to recommend whether DEH fleets of light trucks should either convert to one of these fuels or continue using gasoline.

Approach

A background investigation identified current government and private industry use of CNG and propane. The primary source of information was the U.S. Department of Energy's latest assessment of gaseous vehicle fuel technology.[1] The DOE study addressed safety and environmental effects, cost of vehicle conversion to both dual fuel and dedicated systems, cost of a refueling station, optimum operational conditions, possible reductions and increases in maintenance costs, and the price relation of gasoline to alternate fuels.

This study proposes an economic model that pertains to U.S. Army installations and includes the following parameters: refueling station costs, vehicle conversion costs, fuel costs, and changes in operation and maintenance costs. Safety and environmental effects are discussed but are not quantified.

Vehicle data collected from three Army installations were used in the model. Economic payback analyses were performed for various fleet scenarios. Sensitivity analyses were performed by varying the costs associated with certain parameters of the model.

[1] *Gaseous Fuel Vehicle Technology State of the Art Report, Draft* (Department of Energy, March 1988).

Scope

This study is limited to light trucks at Continental United States (CONUS) installations and their conversion to the use of propane or compressed natural gas.

Mode of Technology Transfer

The economic model proposed in this study will be incorporated into the larger DEH Equipment Repair/Replacement Model being developed under AT41-SB-CGO, "DEH Equipment Maintenance Management System."

2 PROCEDURE

Background

This study used and built upon the U.S. Department of Energy study which investigated the current use of compressed natural gas and liquefied petroleum gas as alternative transportation fuels. The DOE study also proposed an economic model to predict the feasibility of conversion from gasoline or diesel fuel to the alternate gaseous fuels. The topics addressed in the DOE study formed the parameters for the economic model proposed in this study. While this economic model is based on the DOE study, it applies specifically to the conditions affecting U.S. Army installations and the maintenance of their fleets of light trucks.

Model Postulation

The following types of parameters were included in the general model:

1. Refueling station costs--alternative costs for both the fast fill and slow fill methods
2. Vehicle conversion costs--costs for dual fuel and dedicated systems
3. Fuel costs--current and projected costs for gasoline and the alternate fuels
4. Changes in operation and maintenance costs--changes in maintenance costs: fewer tuneups, oil changes, storage cylinder recertification, and additional utilities costs.

Vehicle Data Collection

For the sampled installations, vehicle age, expected useful life, gasoline consumption, type of fuel system (spark-ignited carbureted or fuel-injected), type of control system (conventional or computer-controlled), and annual mileage were collected. Figures 1 and 2 show the data collection forms used.

Model Development

In this phase, the form of the model was developed. The model allows for economic payback analyses using an appropriate (10 percent) discount rate.* The analyses compare operating costs under the use of gasoline with the same costs under the use of both alternate fuels. Economic payback would occur when the accumulated present worth of capital and operating expenses using an alternate fuel is less than the accumulated present worth of operating costs using gasoline.

Model Simulation

Sensitivity analyses were performed by varying certain parameters of the model. Best- and worst-case scenarios were developed by varying combinations of fleet mileage and size, fuel cost, percent of alternate fuels used (under the dual fuel systems), type of refueling station, and percent difference between the mileage of vehicles using alternate fuels and those using gasoline.

*The Office of Management and Budget mandates a discount rate of 10 percent.

FOR EACH OF YOUR LIGHT TRUCKS, PLEASE PROVIDE THE FOLLOWING INFORMATION:

YEAR	MAKE MODEL	AVERAGE ANNUAL MILEAGE	AVERAGE MILES PER GALLON	EXPECTED USEFUL LIFE (YEARS)	MAXIMUM DAILY DRIVING RANGE	FUEL/IGNITION SYSTEM CHARACTERISTICS				
						CARBURETOR (YES/NO)	INJECTED (YES/NO)	SPARK IGNITION (YES/NO)	COMPRESSION IGNITION (YES/NO)	COMPUTER CONTROLLED (YES/NO)

Figure 1. Fleet characteristics data collection form.

PLEASE PROVIDE THE FOLLOWING ADDITIONAL INFORMATION:

1. What is the typical (average) Salvage Value of a light truck given as a percentage of purchase price? _______ %

2. For the Calendar Years shown, indicate the cost per delivered gallon of gasoline.

1984	1985	1986	1987	1988	1989	1990

3. For the Calendar Years shown, indicate the cost per delivered Standard Cubic Foot of Natural Gas.

1984	1985	1986	1987	1988	1989	1990

4. For the Calendar Years shown, indicate the cost per delivered gallon of Propane.

1984	1985	1986	1987	1988	1989	1990

5. If any of your light trucks operate using diesel fuel, indicate the cost per delivered gallon.

1984	1985	1986	1987	1988	1989	1990

6. Please make any comments regarding the use of Compressed Natural Gas or Propane as a fuel for your fleet of light trucks. Attach additional pages, if necessary.

Figure 2. Vehicle and fuel price data collection form.

3 RESULTS AND ANALYSIS

Many fleet managers and operators hesitate to convert vehicles from gasoline to CNG or LPG because they do not understand the process of conversion or the advantages it offers. This comprehensive economic model will help decisionmakers determine the economic feasibility of such a conversion.

Vehicle Modification Requirements

There are two types of alternate fuel vehicles, dual fuel, and dedicated alternative fuel vehicles. Dual fuel vehicles may operate on either the alternate or a conventional fuel. For dual fuel vehicles, alternate fuel operation is performed by adding hardware to the existing conventional fuel system of the vehicle. Since internal engine modifications are usually not made, optimization with either fuel is difficult. Dedicated alternate fuel vehicles can operate only on the alternate fuel; unnecessary petroleum fuel system hardware is removed. Various internal engine modifications are made to optimize engine performance.

CNG Systems

One component of a CNG system is the storage tank. There are a number of steel cylindrical tanks certified by the U.S. Department of Transportation (DOT) from which to choose. They usually have a diameter of 10 in.* and a length of 36 to 56 in. Because CNG is a gaseous fuel, its density is very low and, at ambient conditions, only a small amount of CNG can be stored per unit of volume. Therefore, CNG is stored under high pressure (generally 2400 to 3000 psi) to increase energy storage density and improve vehicle range. Cylinders can weigh from 105 to 180 lb each for capacities between 300 and 450 cu ft at standard atmospheric pressure, referred to in this report as standard cubic feet (scf). For dual-fueled light trucks, the tanks are normally mounted in the truck bed, which greatly reduces their cargo capacity. In dedicated vehicles, the tanks normally replace the conventional fuel tank, if size, shape, and ground clearance permit.

A network of high and low pressure fuel lines transfer the CNG from the storage tanks to the engine. A fuel fill valve connects to the high pressure line for cylinder filling. For dual fueling, two fuel shutoff solenoids are placed in both fuel lines, one for gasoline and one for natural gas. A fuel selector switch allows switching between fuels. The natural gas shutoff solenoid closes when the ignition key is off or when there is no engine vacuum to prevent CNG flow into the engine.

LPG Systems

Because of its low boiling temperature, LPG storage tanks must be pressure vessels. Normally, LPG storage tanks are DOT-certified to a minimum service pressure of 240 psi. Although LPG fuel tanks are not filled to nearly as high pressures as are CNG tanks, heat exchange to the LPG in the tank can produce vapor pressures exceeding 200 psi. Mounting of the storage tanks is the same as for CNG systems.

LPG tanks are connected to the engine using a network of fuel lines. The fuel is filtered before it enters the engine. Fuel gauges are incorporated on the LPG fuel tank. Both dual-fueled and dedicated fuel systems use fuel shutoff solenoids. To ensure that the LPG solenoid stays closed when the engine

*Metric conversion table is included on p 33.

is off but the ignition is on, a vacuum switch in series with the shutoff solenoid breaks the circuit to the shutoff solenoid if no vacuum is present.

Safety

Two of the greatest concerns with the use of compressed fuels are those of explosion upon impact and fire potential caused by leakage. The DOT sets standards for the safe transportation of hazardous substances, including natural gas. Since certain constituents of natural gas are corrosive to steel tanks in the presence of water, the DOT requires testing of fuel and storage tanks every 5 years. Propane storage tanks may be certified for 5, 7, or 12 years.

One recent study of accidents involving natural gas vehicles consisted of a vehicle crash test and a fire test. The crash test consisted of rear end collisions between a stationary CNG vehicle and a 50 mph "bullet" vehicle. Table 1 shows the test conditions and results of the impact. Although the CNG fuel systems were slightly dislocated, no fuel leakage occurred. The fire test consisted of setting a dual fuel vehicle on fire and recording the results. The gasoline tanks on these dual fuel vehicles were filled with water and the CNG tanks filled to 1100 psi. After 35 minutes, no explosion had occurred and no tanks ruptured. However, in one of the vehicles, the high pressure regulator did melt away, allowing fuel to be burned off.

In similar tests using propane-powered vehicles, failure occurred at the fill fitting on the tank, allowing fuel to release. However, the vapor dissipated without combustion. In another vehicle, the hose to the filling vent was severed and resulted in fuel release, but the propane vapor dissipated without combustion. During the fire test, short flareups of approximately 2 seconds occurred after each pressure release. Tables 2 and 3 show the results of these tests.

Table 1

Canadian Crash Test Results (CNG)

Vehicle Model Year	Model	Powered by	Amount of Fuel	Position of Tank	Bullet Car Release Speed (mph)	Description of Fuel System After Impact
1981	Ford Econoline	Gasoline	Approx 1 gal	Stock	50.01	Tank was not disturbed
1981	Ford Econoline	CNG	850 psi, gasoline tank filled with water	Behind driver seat on cargo floor	48.72	Tanks and supply lines dislocated slightly but system held pressure
1981	Oldsmobile Omega	Gasoline	Approx 1 gal	Stock	49.47	Tank was deformed but did not leak
1981	Oldsmobile Omega	CNG	1100 psi, gasoline tank filled with water	In trunk, under parcel shelf	44.66	Tank dislocated slightly but system held pressure

Table 2

Canadian Crash Test Results (Propane)

Vehicle Model Year	Model	Powered by	Amount of Fuel	Bullet Car Position of Tank	Description of Release Speed (mph)	Fuel System After Impact
1981	Ford Econoline	Gasoline	Approx 1 gal	Stock	50	Tank was not disturbed
1981	Ford Econoline	Propane	Full, gasoline tank removed	Forward of and slightly below rear bumper	48	Fill fitting snapped off at tank resulting in release of fuel at a slow rate; vapor dissipated with no combustion
1981	Oldsmobile Omega	Gasoline	Approx 1 gal	Stock	49.5	Tank was deformed but did not leak
1981	Oldsmobile Omega	Propane	Full, gasoline tank removed	In trunk, just behind parcel shelf	47	Hose to filling vent severed resulting in slow release of fuel; vapor dissipated with no combustion

Table 3

General Summary of Canadian Fire Test

Vehicle Model Year	Model	Powered by	Amount of Fuel	Number of Tanks	Significant Events
1981	Dodge Ram	Gasoline	1/2 full	1	Plastic fuel tank melted; test deemed complete after 30 min
1981	Dodge Ram	Propane	3/4 full	1	Pressure release valve operated after 9 min of burning, resulting in a flareup of approximately 2 sec, directly towards the rear of the vehicle; valve operated similarly two more times at 10 and 11 min; valve melted out at 12 min and flareup continued for approximately 7 min; rapid burning around the headliner was noted, probably due to leakage at the fuel gauge sensor; test deemed complete after 25 min

Environmental Impacts

Light duty trucks are in one of the six classes of vehicles in the transportation sector whose emissions are regulated. Since there are no federal exhaust emission standards for gaseous-fueled vehicles, comparison can be made only with gasoline emission standards or baseline gasoline operations. Results from federal test procedures dynamometer emission tests from dedicated natural gas or dual-fueled natural gas vehicles are compared with preconversion gasoline vehicles in Tables 4 and 5.

Compressed Natural Gas

Table 4 shows emission ranges for light duty trucks by vehicle year. Most pre-1979 trucks showed higher baseline gasoline emissions when fueled with natural gas, probably because they did not use extensive emission controls.

Table 4

Comparative Emissions: CNG and Gasoline Trucks

	Emission	Actual Tests Percent Change From Gasoline Baseline Vehicle Emissions*	Comments
PRE-1979	CO	-87 to -98	Based on limited number of tests; almost all carbureted, noncatalyst vehicles
	NOx	-8 to -65	Based on limited number of tests; depends on whether spark timing adjustment is used
	HC (total)	+215 to -46	Based on limited number of tests with wide variation in data; mostly methane
1979-1983	CO	-23 to -94	Depends on CNG fuel system calibration
	NOx	-27 to -60	Depends on the spark timing adjustment
	HC (total)	+729 to -84	Wide variation in data; large percentage increases are due to lower base HC emissions
POST-1983	CO	+80 to -99	Depends on CNG fuel system calibration
	NOx	+73 to -65	Depends on spark timing compensation and emission system interaction
	HC (total)	+1071 to +200	

*There are no federal exhaust emissions standards for gaseous-fueled vehicles; all comparisons were made with gasoline emission standards.

CNG emission control performance decreased relative to gasoline in post-1979 trucks, probably because these vehicles had to meet more stringent emission controls. In post-1983 models, the probable carbon monoxide and nitrogen oxide emission ranges were found to be lower (with proper calibration of fuel system and timing) for natural gas vehicles than for gasoline-fueled vehicles. Although total hydrocarbon emissions for natural gas vehicles were found to be much higher than their gasoline vehicle counterparts, these emissions are composed mostly of methane, which is thought to be nonphotochemically reactive and therefore less dangerous than the hydrocarbon emissions of gasoline.

Liquefied Petroleum Gas

Table 5 shows results of exhaust emission tests comparing LPG with gasoline-powered light duty trucks. Much of the variation in the emission results is due to variation in test engine tuning while running on LPG or to tuning to lower a specific emission (e.g., lowering the amount of fuel in the fuel-air mixture to reduce carbon monoxide emissions), which also alters other emissions from the vehicle. In addition, variations in LPG conversion kits and differences in vehicle emission control devices provide emissions variations. For the most part (depending upon fuel system calibration and timing), total hydrocarbons, nitrogen oxides, and carbon monoxide emissions were found to be lower in LPG-powered vehicles than in gasoline-powered vehicles.

Operational Characteristics

Since CNG fuel for vehicles is not widely dispensed like gasoline, the fleet owner must provide for dispensing. Therefore, the most desirable vehicles for dedicated CNG operation will have regular operational modes (urban or highway), local or short range routes, easy access to CNG, and return to central locations after daily use.

Performance

Engine power loss is one of the largest drawbacks to the use of natural gas in spark ignition engines. CNG and LPG fuels are gaseous at standard atmospheric pressure and have lower volumetric efficiency than liquid fuels. Gaseous fuels show inherent losses of 10 percent in power under fully optimized conditions due to the larger air displacement upon intake that results in leaner combustion. This effect, coupled with the higher vehicle weight due to the CNG and LPG fueling equipment, generally results in slower acceleration than in gasoline-powered vehicles. Computer-controlled and fuel-injected systems pose many technical limitations for natural gas use. Fuel injector design and durability, and computer/engine system integration are incompatible with natural gas dual fuel systems.

Fuel Economy

A miles per gallon equivalent (mpg_e) is used to compare fuel economy between CNG and LPG-fueled vehicles and those operated with gasoline. A gallon equivalent refers to the amount of alternate fuel in standard cubic feet (for CNG) or gallons (for LPG) which equals the energy content of a gallon of gasoline. CNG has a gallon equivalent of approximately 125 cu ft at standard atmospheric pressure; LPG has a gallon equivalent of approximately 1.43 gal. Tables 6 and 7 show results for several chassis dynamometer and in-use tests performed in Canadian studies using CNG and LPG test vehicles. The last data entry in Table 7 is from a test performed by the California Air Resources Board. Note that the results for CNG tests are given in terms of fuel economies relative to gasoline, while those for LPG are

given in terms of fuel consumption relative to gasoline, so that on an energy content basis, a 25 percent increase in LPG consumption represents only a 13 percent gain in mpg_e.

Range

Driving range with CNG and LPG is less than with gasoline operation due to lower energy storage capacity; for equivalent storage tank water volumes, CNG and LPG store much less energy than does gasoline. Therefore, CNG is normally stored under high pressure (2400 to 3000 psi), and LPG is normally stored at pressures between 80 and 200 psi. Table 8 shows a comparison of dimensions (diameter by length), driving range, and weight for three types of fuel tanks of the same water volume. Thus, a CNG-powered vehicle would require four times the storage capacity of a gasoline-powered vehicle to achieve the same driving range.

Table 5

Comparative Emissions: LPG and Gasoline Trucks

	Emission	Actual Tests Percent Change From Gasoline Baseline Vehicle Emissions	Comments
PRE-1979	CO	+29 to -93	Based on limited number of tests; some vehicles equipped with oxidation catalysts
	NOx	-23 to -79	Based on limited number of tests; depends on whether spark timing adjustment is used; some vehicles equipped with EGR
	HC (Total)	0 to -62	Based on limited number of tests; some vehicles equipped with oxidation
1979-1983	CO	-56 to -95	Depends on LPG fuel system calibration
	NOx	-15 to -83	Depends on the spark timing adjustment; most vehicles equipped with EGR
	HC (Total)	-19 to -69	Most vehicles equipped with oxidation catalysts
POST-1983	CO	+48 to -88	Depends on LPG fuel system calibration
	NOx	+91 to -70	Depends on spark timing compensation and emission system interaction
	HC (Total)	+39 to -69	Percentage based on difference in emission values between tests for Total HC and California emission standards for nonmethane HC

Table 6

Fuel Economies Relative to Gasoline for CNG Vehicles

Fleet or Organization	Type Vehicle	Number of Vehicles	Model Year	Average Percent Change in mpg_e	Driving Cycle	Comments
Consumer's Gas Co., Ltd.	LD truck	1	1984	-4	EPA city	Dual fuel Ford Ranger
	LD truck	1	1984	-8	EPA highway	Dual fuel Ford Ranger
	LD truck	1	1984	-5	EPA city	Dedicated Ford Ranger
	LD truck	1	1984	-11	EPA highway	Dedicated Ford Ranger
Energy, Mines and Resources Canada	LD truck	1	1981	-7 -2 -2 -8 -1 -2	EPA city	Dual fuel; 6 different kits
	LD truck	1	1981	-4 -1 0 0 +1	EPA city	Dual fuel; 5 different kits

Table 7

Fuel Consumption for LPG Relative to Gasoline

Fleet or Organization	Type of Vehicles	Number of Vehicles	Model Years	Dual Fuel or Dedicated	Percent Change in Fuel Consumption: Urban Driving Cycle	Percent Change in Fuel Consumption: Highway Driving Cycle	Dynamometer or In-Use Data
Environment Canada Program	LD trucks	2	1981	Dedicated	+35	+44	Dyna
	LD truck	1	1981	Dedicated	+19	+14	Dyna
Manitoba Telephone System	LD trucks and vans	25	1978-1980	Dedicated	+25		In-use, normal driving
Calif. Air Resources Board	LD truck	1	1983	Dedicated	+31		Dyna

Table 8

Dimensions, Driving Range, and Weight for Fuel Tanks of Same Water Volume

Type of Fuel	Type of Tank	Exterior Dimensions (in.)	Internal Water Capacity (U.S. gal)	Energy Content (gal equiv)	Driving Range	Weight (lb)
Gasoline	Conventional	12.4 x 19.7	13.2	13.2	300 mi	11.0
LPG	Steel	12.4 x 29.5	13.2	9.0	200 mi	50.6
CNG	Steel	12.4 x 32.9	13.2	3.3	75 mi	123

Refueling Station Requirements

CNG and LPG refueling stations have certain requirements and characteristics. Specific refueling capacities and their associated cost estimates will apply to the economic model.

CNG Systems

There are two methods of CNG refueling, the fast and slow fill methods. Fast fill systems can refuel a vehicle in 3 to 5 min. These systems consist of a rack, or "cascade," of high pressure storage cylinders, one or more multistage compressors, and a flow measuring and control system. The cascade is usually arranged in at least three banks of cylinders. The cylinders in each bank are manifolded together so that each bank acts as one large container. Normally, natural gas from utility pipelines is routed into the system compressor, which charges the banks of the cascade by priority fill, i.e., high pressure banks first (to approximately 3600 psi) followed by successively lower pressure banks. The cascade is connected to a filling manifold comprised of fill-vent valves and flexible filling hoses which refuel the CNG vehicles. Vehicle tanks are filled through a series of pressure balances. The first bank of the cascade pressurizes the vehicle storage cylinder to approximately 1600 psi, the second bank fills the cylinder to 2000 to 2500 psi, while the third bank (if it is able to) tops off the cylinder to its maximum operating pressure (2400 to 3000 psi). If the last bank is unable to complete the process, the compressor finishes the refueling. After vehicle refueling is complete, the fill vent valves are closed, and the CNG left in the fill hoses is vented to the atmosphere about 10 ft above ground. The compressor then charges the cascade by priority fill.

Slow fill CNG refueling systems are essentially the same as fast fill systems, except that a cascade is not required; the compressor directly changes the fuel tanks. The compressor system charges a manifold which is connected to fill posts or hose-drop assemblies. Each fill post has a number of fill-vent valves, hoses, and couplings, so that many vehicles can be serviced during one refueling period. Slow-fill refueling can take several hours, so vehicles are normally dropped off at the station at the end of the business day for refueling and next day pickup.

Meters are placed on the high pressure side of the compressor to indicate the amount of natural gas dispensed. Some CNG dispensers look and function like commercial gasoline pumps; those offered in Canada, New Zealand, and Italy provide automatic refueling and billing capabilities.

LPG Systems

Most LPG refueling stations incorporate large bulk storage tanks for vehicle refueling. The bulk storage tanks are DOT and ASME (American Society of Mechanical Engineers) certified. Sizes range from 1000 to 30,000 gal water capacity. Capacity depends on the number of vehicles in the fleet, how often LPG is delivered, the quantity used, and how much reserve is desired. A pressure line from the bulk storage tank is connected to the vehicle with a leaktight fitting. LPG fuel transfer is performed through pressure differential, gravity feed, or positive displacement pumps. LPG tanks are normally filled to only 80 to 85 percent capacity to allow for fuel expansion. Automatic fuel metering shutoff controls are available for proper tank filling and to ensure the shutoff of fuel flow in case filling lines are ruptured. Metering of the LPG during refueling is usually done with positive displacement devices. There are meters available with vapor eliminators (since vapor causes inaccurate measurements), temperature-volume compensators (for readout correction), built-in billing information, remote operation and control, locking features, and either zero-start or accumulative totaling.

Technical Limitations

There are a number of technical limitations to the efficient overall operation of alternate fuel vehicles. Greater vehicle weight hurts fuel economy, range, and performance. Furthermore, most vehicle conversion kits do not interact with the exhaust emission control hardware.

Vehicles with electronic fuel injection pose real challenges to the engineering of vehicle conversion systems. Many fuel injection systems do not allow alteration of the fuel system without a disabling effect. Moreover, these systems do not allow the changes to ignition timing essential for efficient, clean alternate fuel use.

Economic Model

This general economic model can help in determining whether to convert a fleet of light duty trucks from the use of gasoline to an alternate fuel. The model parameters and their cost estimates, and the model equations, will combine to create best-, average-, and worst-case economic comparisons between gasoline and alternate fuels.

Model Parameters and Cost Estimates

There are 17 parameters included in this model. Cost estimates were obtained from the Department of Energy, DEH fleet managers, and conversations with two city fleet managers who are in the process of converting to an alternate fuel. Parameters (and associated cost estimates) identical in both gasoline and alternate fuel use are not included in the model. For example, if the cost of electricity to operate pumps and meters is thought to be identical in both cases, it is excluded. Therefore, the cost of electricity to operate a CNG compressor station (not present in a gasoline station) has been included in the model.

Parameter P_1: Fleet Mileage This parameter denotes the total miles driven by a fleet during a typical year. Data collected from several Army installations showed an average annual mileage per vehicle of 5000 miles, ranging from 3000 to 10,000 miles.

Parameter P_2: Miles per Gallon The average for a vehicle in the fleet varies from 9 to 15 mpg.

Parameter P_3: Cost of Gasoline The average cost per gallon of gasoline to the Government was $0.70.

Parameter P_4: Inflation Rate of Gasoline The model uses a 3 percent rate of inflation of gasoline prices. This is consistent with recent DOE studies.

Parameter P_5: Cost of the Alternate Fuel This parameter is expressed as the Cost per Gallon Equivalent of the alternate fuel. (Approximately 125 scf of CNG and 1.43 gal of LPG have the same energy content as 1 gal of gasoline.)

Parameter P_6: Inflation Rate of the Alternate Fuel The model uses a 2 percent rate of inflation for the cost of CNG and LPG. This is consistent with recent DOE studies.

Parameter P_7: Percent Alternate Fuel Used This parameter denotes the percentage of time a vehicle runs on the alternate fuel. For dedicated alternate fuel vehicles, the value is 100 percent; for dual fuel vehicles, the value can vary.

Parameter P_8: Percent Change in MPG Using an Alternate Fuel Estimates for this parameter will vary from 10 to -10 percent depending upon the alternate fuel used. Some in-use mileage tests have indicated a range from zero to -10 percent difference in mpg using CNG and a range from 10 to and zero percent difference in using LPG.

Parameter P_9: Average Vehicle Maintenance Savings This parameter denotes only the cost of tuneup and oil change savings when using an alternate fuel. The DOE has estimated that two tuneups over a 10-year vehicle lifetime could be eliminated; one fleet manager using alternate fuel vehicles confirmed that common practice is to expand oil change intervals from 3000 to 6000 mi.* Parts and labor for an oil change are estimated to cost $10, for a tune up, $30.

Parameter P_{10}: Inflation Rate of Parts and Labor A 3 percent inflation rate is applied to costs of maintenance parts and labor.

Parameter P_{11}: Cost of Vehicle Conversion Table 9 shows typical costs for conversion to either CNG or LPG. Costs are taken from a DOE survey of numerous distributors nationwide. In order for a CNG vehicle to achieve a reasonable range, it is assumed that it requires two storage tanks; an LPG vehicle requires only one. In the conversion process, cages are installed around the storage tanks to protect them from cargo damage.** Estimated cost was $200 for parts and $100 for labor.

Parameter P_{12}: Cost of Tank Recertification Both vehicle storage tanks and refueling station tanks must be recertified every 5 years at an estimated cost of $100 per tank.

Parameter P_{13}: Cost of Removal of Conversion Equipment Upon Vehicle Disposal This is estimated to be 50 percent of the labor cost of installation.

Parameter P_{14}: Cost of Construction of Refueling Station Estimates for costs of site preparation, construction, and installation of the refueling equipment depend upon the specific installation.

---

*David Burns, Fleet Services Supervisor, City of Tucson, AZ, 9 Nov 1988.

**Gary Grenee, Motor Pool Supervisor, Arizona State University, Tempe, AZ, 8 Nov 1988.

Table 9

Costs for CNG and LPG Conversion

	Conversion Kit	Cost per Tank	Protective Cages	Installation	Cost Range
	$840 - $1000	$450 - $500	$200	$650 - $800	$2390 - $2900
	$800 - $900	$400	$200	$600 - $700	$2400 - $2600
C	$700	$300 - $400	$200	$600 - $700	$2100 - $2400
N	$850	$325	$200	$300	$2000
G	$640	$140	$200	$450 - $600	$1570 - $1720
	$720	$320	$200	$380	$1940
				Av Cost Range:	$2070 - $2260
	$600	$300 - $400	$200	$600 - $700	$1700 - $1900
L	$600 - $800	$200 - $500	$200	$300	$1300 - $1800
P	$450 - $550	$300 - $400	$200	$650	$1600 - $1800
G	$275 - $375	$200 - $300	$200	$300	$ 975 - $1175
				Av Cost Range:	$1390 - $1670

Requirements range from running utility lines and minimal site preparation (to adapt an existing gasoline station) to construction of a new facility. One fleet manager* in the process of converting approximately 100 vehicles (mostly light trucks and sedans) indicated that the preliminary engineering estimate for a new refueling station (facilities and equipment) was $300,000: $150,000 for equipment and $150,000 for the facility. This model assumes "middle-of-the-road" construction and installation costs, from $20,000 to $60,000.

Parameter P_{15}: Refueling Station Cost A general model is based upon many assumptions about the cost of a refueling station. The type of equipment a station requires depends on the purpose of the individual installation. The capacity of a station depends on the number of vehicles in the fleet, how much and how often fuel is delivered, the quantity of fuel that will be used, and in the case of LPG, how much reserve is desired. A small (up to 40 light trucks) DEH fleet operating on CNG would require a compressor station with two cascades, two nozzles, and two meters. A small DEH fleet operating on LPG would require a pump, two meters, a dispenser with two hoses, and one or two 1000 gal storage tanks. To estimate the fuel delivery capability required of the compressor, this model uses an average daily gasoline consumption and converts it to a standard cubic foot per minute (scfm) requirement (the unit of measure by which compressors are purchased). Table 10 shows ranges of estimates for other components of the refueling station. Components and cost estimates for medium and large DEH fleets are obtained by proportionately increasing estimates of small DEH fleet requirements. Equations for calculating compressor requirements are presented in the Model Equations below.

*Richard Quintas, Motor Pool Supervisor, City of Tucson, Tucson, AZ, 3 November 1988.

Table 10

Refueling Station Components Costs

	Component	Cost Range
C	Cascades (2)	\$12000 - \$18000
N	Meters (2)	\$ 6000 - \$12000
G	Dispenser (2 nozzles)	\$23000 - \$32000
	Fuel posts (2, slow fill)	\$ 1000
L	Pump	\$ 900 - \$ 1400
P	Meters (2)	\$ 4000 - \$ 6000
G	Dispenser (2 hoses)	\$ 6000
	Storage tank (2 @ 1000 gal)	\$ 2000 - \$ 3000

Parameter P_{16}: Refueling Station Maintenance Cost A Department of Energy report indicates an average annual maintenance cost of \$0.08 per gal equivalent is required for maintenance of the compressor in a CNG refueling station. The cost to maintain an LPG refueling station is considered to be the same as to maintain a gasoline station and is not included in the model.

Parameter P_{17}: Compressor Station Operation Cost The cost of electricity to operate a CNG compressor is based upon a 100 scf/kWh compressor energy requirement at a rate of \$0.07/kWh.

Model Equations

Equations for calculating costs of the baseline operation (gasoline) and the two alternatives (CNG and LPG) are classified into capital costs and annual fuel, operating, and maintenance cost categories. Costs are given in terms of the model parameters stated above, as well as other parameters introduced as necessary. In addition to the assumptions and cost estimates described in the preceding paragraph, the following assumptions are made:

1. The expected useful life of the refueling stations is 20 years, a period consistent with assumptions made in a recent DOE study

2. Vehicle refueling occurs within an 8-hour period

3. The expected useful life of light trucks is 10 years

4. Lifecycle cost estimates are based on a 10 percent discount rate

5. Costs common to all baseline and alternative scenarios (such as electricity to operate pumps and meters, or maintenance of refueling station physical facilities) are not included in the model.

Capital Costs: For alternate fuel use, capital costs are calculated as C:

$$C = N \cdot (P_{11} + P_{14} + P_{15}) \qquad \text{[Eq 1]}$$

where N = the number of light trucks in the fleet
P_{11}, P_{14}, and P_{15} are three of the model parameters given above.

For gasoline operation, there are no capital costs. The compressor capability requirement for CNG can be calculated as:

1. Average daily fuel consumption is calculated by dividing the annual fleet gasoline consumption by the number of workdays in a year (approximately 247)

2. Average daily fuel consumption is adjusted for the percentage of time CNG will be used (in dual fuel vehicles)

3. Average daily fuel consumption is adjusted for anticipated mpg increase or decrease.

4. The resulting number is multiplied by 125 (the number of standard cu ft equivalent to a gallon of gasoline) and divided by 480 (the number of minutes in a work day).

This completes the first phase of the calculation and yields a quantity, R, which represents the scf/min capability required of the compressor.

Based on a DOE survey of costs for various compressor sizes, the following rule of thumb was developed for compressor capabilities between 20 and 100 scf/min: if R represents the required compressor capability, then the cost of the compressor can be calculated as C:

$$C = \$22{,}800 + (\$300 \cdot R) \qquad \text{[Eq 2]}$$

This cost added to other CNG refueling station costs yields an estimate for total equipment costs.

Annual Fuel Costs: For gasoline operation, annual fuel costs are calculated as:

$$F_g = [P_3 \cdot P_1 / P_2] \cdot (1.03)^t \qquad \text{[Eq 3]}$$

where t = the year of operation.

For an alternate fuel, annual costs are given as:

$$F_a = P_7 \, [P_5 \cdot P_1/P_2 \, (1 + P_8)] \cdot (1.02)^t + (1 - P_7) \cdot F_g \qquad \text{[Eq 4]}$$

Annual Operating Costs: This refers to the cost of electricity to run the compressor station and pertains only to CNG operation. The cost is represented as:

$$E = P_7 \, [P_1/P_2 \, (1 + P_8)] \cdot (125 \text{ scf/gal}) \cdot (\$0.07 \text{ /kWh}) / (100 \text{ scf/kWh}) \qquad \text{[Eq 5]}$$

where $P_7 [P_2/P_2 (1 + P_8)]$	=	fuel consumption (in gal)
125 scf/gal	=	the conversion factor between scf of CNG and gallons of gasoline
\$0.07/kWh	=	the typical cost per kWh
100 scf/kWh	=	the number of scf compressed using 1 kWh of electricity by a typical CNG compressor.

Annual Maintenance Savings/Costs: There are no annual maintenance savings or costs considered here for gasoline operation. The following equations (the first for LPG usage, and the second for CNG) include both maintenance savings and additional maintenance costs likely to occur under alternate fuel use. Savings include less frequent oil changes and tuneups. Additional costs include cylinder recertification, labor cost for removal of vehicle conversion equipment upon resale (for both LPG and CNG), and compressor maintenance (for CNG only). The costs for LPG are represented as:

$$\begin{aligned} M_{LPG} = & - (P_7 \cdot P_1 / 6000) \cdot (1.03)^t \cdot (\$ 10) && \text{[Oil Changes]} \\ & - \delta_i \cdot N \cdot (1.03)^t \cdot (\$ 30) && \text{[Tuneups]} \\ & + \delta_k \cdot N \cdot (1.03)^t \cdot (\$ 250), && \text{[Equipment Removal]} \end{aligned} \qquad \text{[Eq 6]}$$

and the costs for CNG are represented as:

$$\begin{aligned} M_{CNG} = & - (P_7 \cdot P_1 / 6000) \cdot (1.03)^t \cdot (\$ 10) && \text{[Oil Changes]} \\ & - \delta_i \cdot N \cdot (1.03)^t \cdot (\$ 30) && \text{[Tuneups]} \\ & + \delta_i \cdot M \cdot (1.03)^t \cdot (\$ 100) && \text{[Tank Recertification]} \\ & + \delta_j \cdot S \cdot (1.03)^t \cdot (\$ 100) && \text{[Tank Recertification]} \\ & + \delta_k \cdot N \cdot (1.03)^t \cdot (\$ 250) && \text{[Equipment Removal]} \\ & + \{P_7 \cdot (P_1 / P_2 [1 + P_8]) \\ & \quad \cdot (1.03)^t \cdot (\$0.08)\}, && \text{[Compressor Maintenance]} \end{aligned} \qquad \text{[Eq 7]}$$

where t = the year of operation

N = the number of vehicles in the fleet

S = the number of vehicle storage tanks in the fleet

M = the number of other storage tanks in a cascade

$\delta_i = \{1, \text{ if } i = \text{yr } 5, 10, 15, \text{ or } 20$; 0, otherwise$\}$

$\delta_j = \{1, \text{ if } j = \text{yr } 5 \text{ or } 15$; 0, otherwise$\}$

$\delta_k = \{1, \text{ if } k = \text{year } 10 \text{ or } 20$; 0, otherwise$\}$.

Sensitivity Analysis Variables

There is considerable variability in the parameters involved in modeling the economic effects of converting to alternate fuel use (e.g., current and projected fuel price relation, cost of conversion equipment, change in vehicle mpg, etc.). In light of this uncertainty, sensitivity analyses established a range of possibilities between best- and worst-case scenarios of alternate fuel use. Table 11 displays the variable parameters, along with their best-, average-, and worst-case values.

Table 11

Sensitivity Analysis Variables

Model Parameter	Best	Average	Worst
Average annual mileage per truck	10000	5000	3000
Miles per gallon	9	12	15
Percent alternate fuel usage	90%	80%	60%
Percent change in mpg_e			
CNG	+ 0%	-5%	-10%
LPG	+10%	+5%	+ 0%
Vehicle conversion costs			
CNG dual fuel	$2070	$2160	$2260
CNG dedicated	$1800	$2000	$2350
LPG dual fuel	$1390	$1530	$1670
LPG dedicated	$1350		
Refueling station construction	$20000	$40000	$60000

Economic Analysis

This model uses a discounted payback analysis with a discount rate of 10 percent. Cost estimates for each year of the 20 year lifecycle are generated by the model equations given above. The 10 percent discount rate is then applied, and equivalent annual costs are generated. Once all of the equivalent annual costs are generated for a given fuel price differential, Equivalent Annual Cost Differences for the best- and worst-case scenarios are obtained by calculating the difference between Equivalent Annual Cost (for alternate fuels) and Equivalent Annual Cost (for gasoline). That is, for a given difference in fuel prices and a given alternate fuel configuration, the worst-case annual costs for gasoline are subtracted from the worst-case annual costs for each alternate fuel, and the best-case annual costs for gasoline are subtracted from the best-case annual costs for each alternate fuel. Economic payback occurs whenever gasoline costs outweigh alternative fuel costs (Figure 3). Table 12 shows these equivalent annual cost differences.

Presentation will be in the form of graphs that show the current difference in fuel prices along the horizontal axis versus the resulting range of equivalent annual cost differences for best- and worst-case scenarios along the vertical axis.

Economics of scale do not apply, since costs for medium and large DEH fleets would increase (or decrease) nearly proportionately to their size. Results are calculated only for small DEH fleets (up to 40 trucks).

The model is not a projection. If the following analyses show an economic payback at a $0.50 per gallon price difference between gasoline and CNG, it means that an economic payback would be realized if the price difference were *now* $0.50 per gallon. If, in the future, the price difference between CNG and gasoline ever reaches $0.50 per gallon, then the values for all other cost parameters in this model must

be adjusted (inflated or deflated) at that time and input to the model to determine whether an economic payback would then occur.

Application of the Model

The model applies to typical small Army installations. Operating characteristics (the number of light trucks in a fleet [40], average annual mileage and fuel consumption, vehicle range, fuel prices, etc.) are based upon data collected from DEH organizations. Analyses are performed for six alternate fuel configurations: CNG dedicated and CNG dual fuel for both the fast fill and slow fill; LPG dedicated, and LPG dual fuel. Table 12 shows the fast fill and slow fill, LPG dedicated, and LPG duel fuel configurations. Also included are the values of some of the model parameters for a CNG and LPG usage, along with the range of values for the sensitivity analysis variables.

Figures 3 through 8 graph the current price difference between gasoline and an alternate fuel by the equivalent annual cost differences of the two different modes of operation (gasoline and an alternate fuel). Pictured are the best- and worst-case scenarios generated using the data in Tables 13 and 14. Shaded areas represent a probable cost difference range between gasoline and CNG or LPG for the near future. The point at which the graph first falls below the horizontal axis represents the cost difference between gasoline and the alternate fuel required for there to be an economic payback within the 20-year period of this analysis under best-case circumstances.

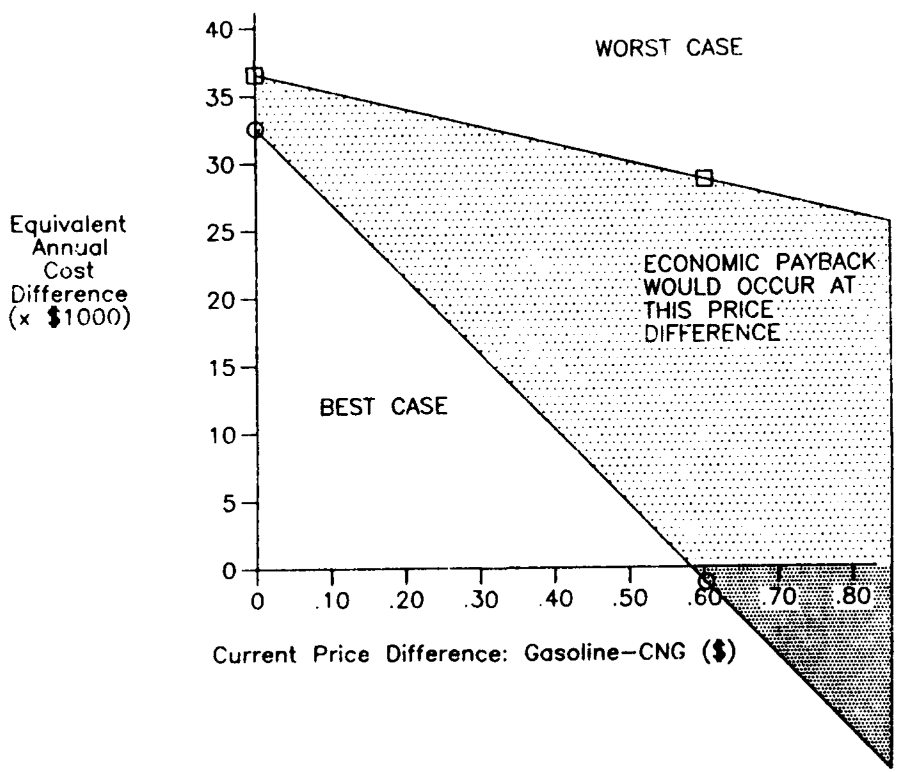

Figure 3. Annual cost by price differences for CNG, fast fill, dedicated configurations.

Table 12

Annual Cost Differences for Best- and
Worst-Case Alternate-Fuel Configurations

Alternate Fuel Configuration		$0.00	$0.10	$0.20	$0.30	$0.40	$0.50	$0.60
CNG, fast fill, dedicated:	best case	$32,028	$26,436	$20,842	$15,249	$ 9657	$ 4065	-$1528
	worst case	$35,333	$34,214	$33,096	$31,977	$30,858	$29,739	$28,622
CNG, fast fill, dual fuel:	best case	$34,970	$29,937	$24,904	$19,870	$14,837	$ 9804	$ 4770
	worst case	$34,999	$34,328	$33,658	$32,987	$32,315	$31,644	$30,974
CNG, slow fill, dedicated:	best case	$27,204	$21,611	$16,018	$10,426	$ 4833	-$759	-$6,351
	worst case	$31,982	$30,863	$29,745	$28,626	$27,507	$26,388	$25,271
CNG, slow fill, dedicated:	best case	$30,478	$25,445	$20,411	$15,378	$10,345	$ 5311	$ 278
	worst case	$31,648	$30,977	$30,307	$29,636	$28,964	$28,293	$27,623
LPG, dedicated:	best case	$21,197	$13,928	$ 6657	-$ 613	-$ 7884	-$15,155	-$22,424
	worst case	$21,763	$20,333	$18,893	$17,454	$16,014	$14,575	$13,134
LPG, dual fuel:	best case	$20,685	$14,142	$ 7,598	$ 1055	-$5488	-$12,032	-$18,575
	worst case	$21,953	$21,090	$20,227	$19,362	$18,498	$17,634	$16,771

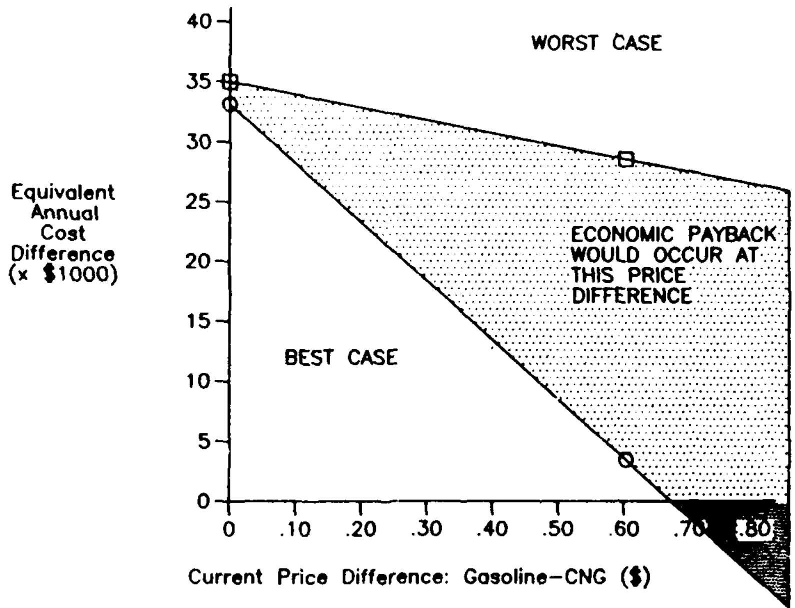

Figure 4. Annual cost by price differences for CNG, fast fill, dual fuel configurations.

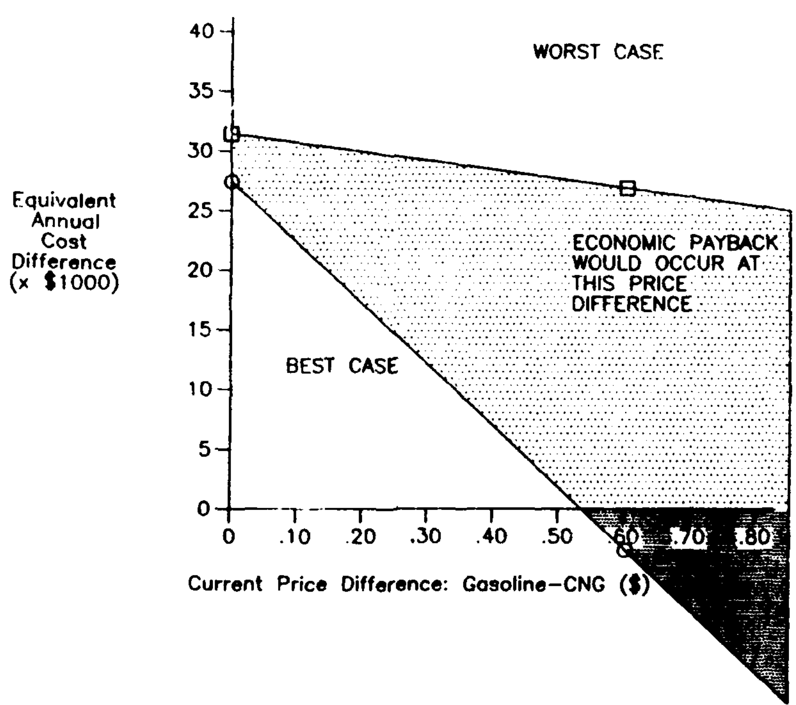

Figure 5. Annual cost by price differences for CNG, slow fill, dedicated configurations.

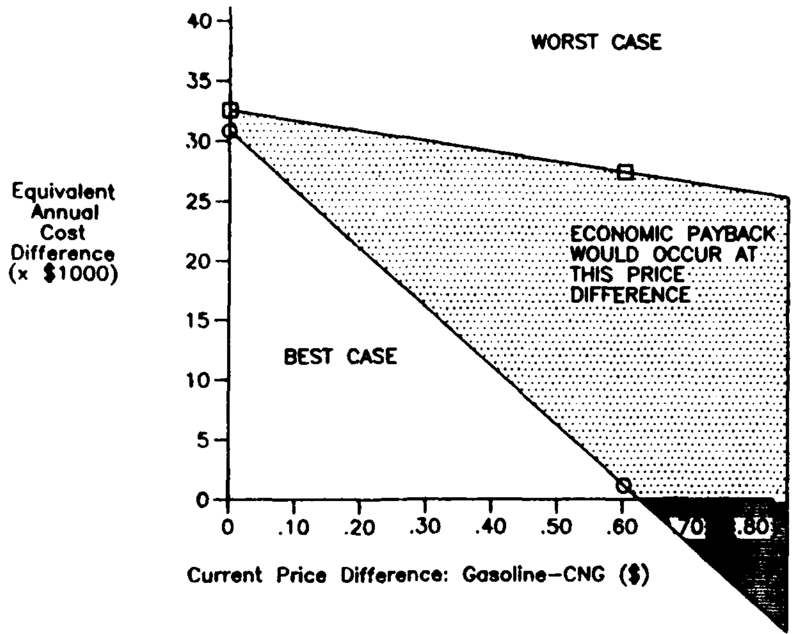

Figure 6. Annual cost by price differences for CNG, slow fill, dual fuel configurations.

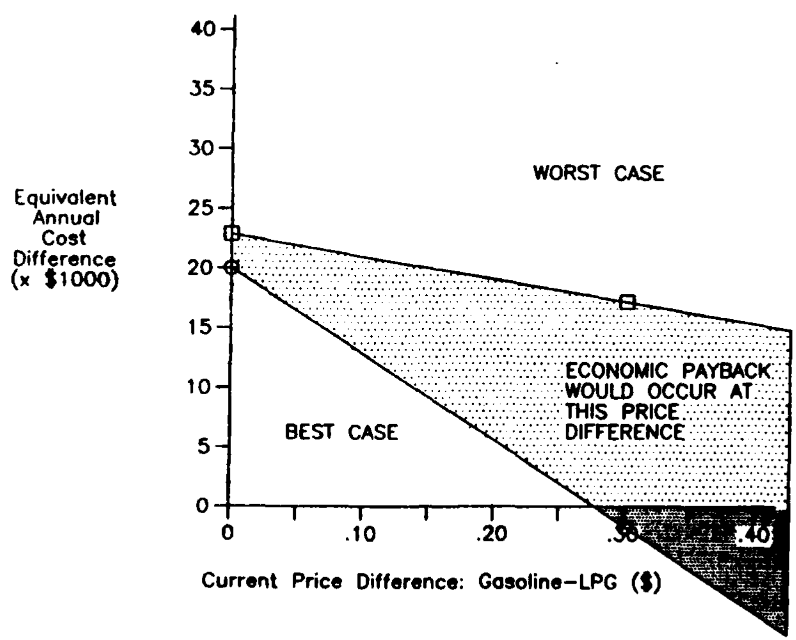

Figure 7. Annual cost by price differences for LPG, dedicated configurations.

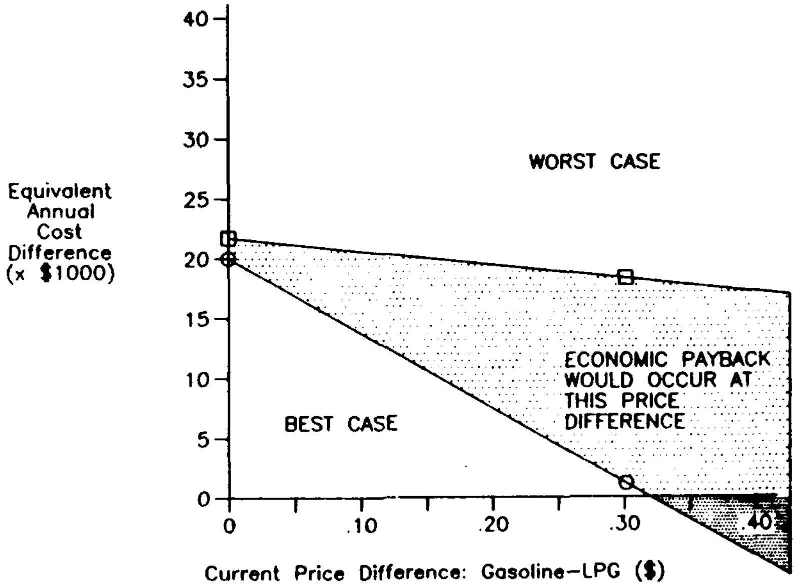

Figure 8. Annual cost by price differences for LPG, dual fuel configurations.

Table 13

CNG Parameter Range for Small Army Installations

Parameter	Average	Best	Worst
Annual fleet mileage	200000	400000	120000
Miles per gal	12	9	15
Cost of gasoline (per gal)	$0.70		
Inflation rate of gasoline	3%		
Current cost of CNG (per gal equivalent)	$0.50		
Inflation rate of CNG	2%		
Percent CNG usage (dual fuel)	80%	90%	60%
Change in mpg	-5%	0%	-10%
Inflation rate for parts and labor	3%		
Cost of vehicle conversion			
dual fuel	$86400	$82800	$90400
dedicated	$80000	$72000	$94000
Removal of equipment (dual fuel)	$1000*		
Cost of construction	$40000	$20000	$60000
Refueling station cost			
fast fill, dedicated operation		$77858	$67450
slow fill (5 fill posts, dedicated)		$54360	$46950
fast fill, dual fuel operation		$76450	$67450
slow fill (5 fill posts, dual fuel)		$52950	$46950

*Years 10 and 20 only

Table 14

LPG Parameter Range for Small Army Installations

Parameter	Average	Best	Worst
Annual fleet mileage	200000	400000	120000
Miles per gal	12	9	15
Cost of gasoline (per gal)	$0.70		
Inflation rate of gasoline	3%		
Current cost of LPG (per gal)	$0.65		
Inflation rate of LPG	2%		
Percent LPG usage	80%	90%	60%
Change in MPG	5%	10%	0%
Inflation rate for parts and labor	3%		
Cost of vehicle conversion			
dual fuel	$61200	$55600	$66800
dedicated	$54000		
Removal of equipment (dual fuel)	$10000*		
Cost of construction	$40000	$20000	$60000
Refueling station cost			
dual fuel	$12900	$14900	
dedicated	$12900	$14900	

*Years 10 and 20 only

4 CONCLUSIONS AND RECOMMENDATIONS

This report models the economic effects of converting light truck fleets on Army installations to propane or CNG as alternate fuels to gasoline.

Under the assumptions and values of the parameters in this model, conversion to the use of CNG as an alternate fuel would show an economic payback within 20 years only under best-case circumstances (using a slow fill refueling method and a dedicated fuel configuration) and only if the price difference between CNG and gasoline were approximately \$0.50/gal equivalent or higher.

Under the same conditions, conversion to the use of LPG would show an economic payback within 20 years only under best-case circumstances (using a dedicated fuel configuration) and only if the price difference between LPG and gasoline were approximately \$0.30/gal equivalent or higher.

Since the current price difference between CNG and gasoline is between \$0.20 and \$0.30/gal equivalent, and since the current price difference between LPG and gasoline is between \$0.05 and \$0.10/gal, it is recommended that DEH fleets that operate under the assumptions and values of the parameters in this model continue to use gasoline as the fuel for their light trucks.

However, certain conditions may exist that vary the parameters in this model. Army installations that already have natural gas compressor stations for purposes other than vehicle refueling may be able to avoid the large initial investment of refueling station construction. Similarly, an installation that obtains a price advantage on such items as vehicle conversion equipment may also reduce the initial cost to such a degree that economic payback occurs at (or lower than) the current price difference between an alternate fuel and gasoline. Therefore, it is also recommended that DEH equipment managers apply this model to their own circumstances to help determine whether conversion to the use of an alternate fuel in the place of gasoline is beneficial at their particular sites.

Metric Conversion Table

1 cu ft	=	0.028 m^3
1 ft	=	0.305 m
1 gal	=	3.78 l
1 in.	=	25.4 mm
1 lb	=	0.453 kg
1 mi	=	1.61 km
1 psi	=	6.89 kPa
1 sq ft	=	0.093 m^3

ACRONYMS

CO:	Carbon Monoxide
CONUS:	Continental United States
CNG:	Compressed Natural Gas
DEH:	Directorate of Engineering and Housing
DOE:	United States Department of Energy
DOT:	United States Department of Transportation
EPA:	United States Environmental Protection Agency
HC:	Hydrocarbons
LPG:	Liquefied Petroleum Gas
mpg:	miles per gallon
mpg_e:	miles per gallon equivalent
mph:	miles per hour
NOx:	Nitrogen Oxide
psi:	pounds per square inch
scf:	standard cubic foot (This is the amount of natural gas in a volume of one cubic foot stored at standard atmospheric pressure.)

DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-P
ATTN: CECW
ATTN: CECW-O
ATTN: CECW-P
ATTN: CECW-RR
ATTN: CEMP
ATTN: CEMP-C
ATTN: CEMP-E
ATTN: CERD
ATTN: CERD-L
ATTN: CERD-C
ATTN: CERD-M
ATTN: CERM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

CEHSC 22060
ATTN: CEHSC-ZC 22060
ATTN: DET III 79906
ATTN: CEHSC-F 22060
ATTN: CEHSC-TT-F 22060
ATTN: CEHSC-FB-I 22060

US Army Engineer Districts
ATTN: Library (41)

US Army Engr Divisions
ATTN: Library (14)

US Army Europe
ODCS/Engineer 09403
ATTN: AEAEN-FE
ATTN: AEAEN-ODCS
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (16)
21st Support Command
ATTN: DEH (12)

Ft. Leonard Wood, MO 65473
ATTN: Canadian Liaison Officer
ATTN: German Liaison Staff
ATTN: British Liaison Officer (2)
ATTN: French Liaison Officer

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

AMC - Dir., Inst., & Svcs.
ATTN: DEH (23)

FORSCOM (28)
FORSCOM Engineer, ATTN: Spt Det. 15071
ATTN: DEH

HSC
Ft. Sam Houston AMC 78234
ATTN: HSLO-F

INSCOM - Ch, Instl. Div.
Arlington Hall Station 22212
ATTN: Facilities Engineer (3)
ATTN: Engr & Hsg Div
Vint Hill Farms Station 22186
ATTN: IAV-DEH

Military Dist of Washington
ATTN: DEH
Cameron Station (3) 22314
Fort Lesley J. McNair 20319
Fort Myer 22211

Military Traffic Mgmt Command
Falls Church 20315

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac, Div. 48090

USAIS
Fort Huachuca 85613
ATTN: Facilities Engineer (3)

WESTCOM
Fort Shafter 96858
ATTN: DEH

Fort Belvoir, VA 22060
ATTN: Australian Liaison Officer
ATTN: Water Resource Center
ATTN: Engr Studies Center
ATTN: Engr Topographic Lab
ATTN: ATZA-TE-SW
ATTN: CECC-R

CECRL, ATTN: Library 03755

CEWES, ATTN: Library 39180

Tyndall AFB, FL 32403
AFESC/Engineering & Service Lab

NAVFAC
ATTN: Naval Civil Engr Lab (3)

Engineering Societies Library
New York, NY 10017

US Government Printing Office 20401
Receiving/Depository Section (2)

Nat'l Institute of Standards & Tech 20899

Defense Technical Info. Center 22304
ATTN: DTIC-FAB (2)